Seismic Evaluation and Retrofit Report

Rancho San Andres Castro Adobe

Watsonville, California

As requested by

Monterey District
Department of Parks and Recreation
State of California

by

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Purpose

This report is a general assessment of the structural condition of the Rancho San Andres Castro Adobe with a focus on needs for seismic strengthening and retrofitting as well as the needed structural repairs. The building was seriously damaged during the 1989 Loma Prieta earthquake and has not been repaired since that time although the building has been largely protected from the weather.

The second purpose of the investigation was to provided alternatives for strengthening the second floor framing. The floor is currently supported by rods which extend down from the roof framing. The desire is to remove these rods and strengthen and/or stiffen the floor for future use. Several options are considered in this report

On April 3, 2003, the site inspection of the Rancho San Andres Castro Adobe was performed. That site inspection and other reports supplied to ELT & Associates are the basis for this report.

This report is divided into six sections.

I. The "Background" section provides a general overview of the fundamental issues and decisions that need to made before a seismic retrofit system can be designed.

II. The "Seismic Retrofit Design Issues" section lists the issues and options that are appropriate for a two-story historic adobe building.

III. The "Condition Assessment" Section provides an overview of some of the condition and earthquake damage of the Rancho San Andres Castro Adobe building.

IV. The "Fundamental Structural Approaches" section provides generic information regarding the seismic retrofit of two story historic adobe buildings.

V. The "Structural Retrofit Recommendations for the Rancho San Andres Castro Adobe" section outlines the specific solutions that are appropriate for use on the Rancho San Andres Castro Adobe within the scope of other work that is being performed on the building at this time.

VI. The "Recommendation for Second Floor Framing" presents several options for improving the strength and performance of the second floor framing system.

The attached documentation for this report includes the following:

1. Photographs of the building (interior and exterior) of the important areas of structural damage and a sketch of the building indicating the nature and location of existing damage.
2. Sketches of a generic two-story building showing anchorage at the roof and floor levels.
3. Schematic drawings of the recommended retrofit measures that could be implemented at the Rancho San Andres Castro Adobe and schematic drawings of the strengthening options for the second floor framing.

Limitations

This report is based upon a three to four hour inspection of the Rancho San Andres Castro Adobe on April 3, 2003. No destructive work was done during that investigation although none seemed necessary for the purposes of this report.

The purpose of this report is to provide a general condition assessment of critical structural features and an overall strategy for the seismic retrofit of the building. The seismic retrofit options are general in nature and the final design will vary depending upon the specific conditions encountered as the details of the design are developed or as new conditions are encountered at the site.

This report is for conceptual design purposes only. The information included is not intended for the final design but intended to be used as guidance for decision-making regarding final design decisions.

I. Background

Adobe buildings have many attractive characteristics. However, their performance during large seismic events is not one of them. Adobe buildings can be extremely hazardous during earthquakes, because the walls are massive, and the building material is weak. Life-safety is a serious issue where there is the potential for the failure of an adobe wall.

Nevertheless, many historic adobe buildings were built to last and many have lasted because of how they were built. Thick-walled adobe buildings can be very durable, especially when combined with a well-designed seismic retrofit system that takes advantage of the positive characteristics of adobe buildings. The thick walls of an adobe building are its principal property that can allow the building to perform well during large seismic events. It is very difficult to overturn a thick adobe wall as it rocks about its base. Adobe is a weak material, particularly in tension, but generally has more than enough capacity in compression. Added elements, such as cables, straps, or even bond beams, can serve as the tensile elements to hold an adobe building together.

Adobe buildings will crack during moderate to large seismic events. Some of these cracks may be substantial and may or may not be repairable.

Life-safety is the first and foremost goal of a seismic retrofit design. Even modern buildings made of modern materials with designs based on current buildings codes may be a complete loss, financially, after a major seismic event. However, the design will be considered a success as long as life-safety has been protected.

A minimal approach to retrofit design is to provide for life-safety but to accept that damage will occur during moderate to large seismic events, such as Richter Magnitudes of 5 or 6, and heavy damage will occur to large to severe seismic events such as Richter Magnitudes of 6, 7 or larger.

A more invasive approach, such as the use of vertical straps or small-diameter center core rods, can have a significant effect on reducing the extent of damage that occurs in all levels of earthquakes. Without center core elements, substantial offsets may occur along cracks lines in adobe walls. These offsets can be several inches without compromising a building's near-term ability to remain standing. However, an offset of two or three inches along a diagonal or horizontal crack may be virtually impossible to repair effectively without rebuilding the entire wall.

Finally, water is the number one problem for adobe buildings. Water intrusion must be controlled. Even when slightly damp, an adobe material may lose 80 to 90 percent of its strength. For many adobe materials, repeated wet-dry cycles can reduce the strength of the adobe to a small percentage of its original strength even when dry. The strength of the adobe near the base of an adobe wall is critical for a thick wall to be able to rock about its base. Water intrusion is most likely to affect the base of an adobe wall. It is essential to examine the base of walls and repair them accordingly for future seismic performance.

II. Condition Assessment

The Rancho San Andres Castro Adobe is a two-story main adobe building with a one-story cocina on the north end. The long axis of the building is oriented in the north-south direction. The roof is a wood-framed gabled roof. A second-story porch is supported by wood columns and extends along the length of the east side of the building. A similar roof overhand extends along the length of the west side of the building, the columns are two-stories in height and there is no intermediate porch level. The front elevation of the building faces east as shown in the composite photos on Sheet PH1.1 and the west elevation is shown in the composite photos on Sheet Ph1.2.

Condition of the adobe

The Castro Adobe suffered significant structural damage during the Loma Prieta earthquake in 1989. The building has not been repaired since 1989 except for repairs required to prevent water intrusion.

All of the walls of the Castro Adobe have suffered crack damage in all walls of the building. The upper third of the south gable end wall collapsed. The northwest corner of the cocina (Room 101) suffered extensive damage and crack offsets. Significant damage occurred around the transverse cross-tie in the east and west walls above the second floor adjacent to the north gable end wall. In addition, more minor cracking occurred most all adobe walls throughout the building.

There is evidence of previous earthquake damage particularly in the north gable end wall. A photograph of this crack is shown in Detail 3 on Sheet PH1.3. The wood-cross tie in the area was likely installed after this crack developed in the north gable end wall. Unfortunately, the cross-tie results in significant concentrated loads at the end of the cross-tie which as caused damage in the adobe walls at the ends of this cross-tie. To prevent further damage at the ends of the cross-ties, it is recommended that the cross-tie be cut at some location along its length.

The other area of significance is the foundation at the south end of the building. Settlement in this area is apparent from the slope of the first and second floors adjacent to the south gable end wall. This area was underpinned with reinforced concrete piers and grade beams in 1986. Since that time, the underpinning appears to be functioning properly and is no longer a progressive problem. Nevertheless, since the south end of the building has previous settlement problems, it likely makes the south gable end wall more susceptible to earthquake damage in the future compared to the wall before settlement had occurred.

Besides the earthquake crack damage, the general condition the adobe material is good. Moisture does not appear to have had a significant impact on building.

Wall thickness

A beneficial feature are the very thick walls of the Rancho San Andres Castro Adobe. The exterior walls on the first floor of the two story building are about 28 inches thick. Wall thickness is the key characteristic of adobe buildings which give them their unique characteristics. The out-of-plane stability of thick walls is much better than that of thin-walled construction.

III. Seismic Retrofit Design Issues

Life-safety is fundamental to any seismic retrofit solution. In addition to life-safety, there are other considerations for a historic adobe building.

A classic approach in recent years has been removal of the roof and roof framing on the entire structure, install a concrete bond beam, anchor the roof and second-floor framing to the walls with epoxy anchors, and replace the roof framing and the roof. This is an approach that is largely effective, with the exception of the second-floor epoxy anchors; however it is less respectful of the historic fabric of the building than I generally recommend.

During the 1990's, the Getty Conservation Institute supported the Getty Seismic Adobe Program (GSAP) a multi-year, multi-disciplinary research effort to investigate damage to historic adobe buildings and to develop innovative retrofit measures for application to historic adobe buildings. I was the principal investigator for this project. The solutions offered in this report are those derived from that research. Two final reports and two interim reports have been issued from that project. The final Planning and Engineering Guidelines from GSAP was released in early 2003.

The preferred seismic retrofit solution is a system of cables, straps, and anchors that leave the roof system in place except for removal of the roof over the tops of the adobe walls for placement of anchors. Cables and straps can be placed on interior or exterior walls with minimal effect on the plaster or stucco and less effect, such as one-inch grooves, on the underlying adobe.

Small-diameter center core rods are the most structural effective of retrofit measures examined as part of GSAP. These center core rods are not reversible but have a minimal impact on the historic integrity of the building. They also have a tremendous effect on the seismic performance. These center cores rods are approximately 3/4 inch epoxied steel or Fiberglas rods placed in 2-inch diameter holes filled with a cementitious grout or epoxy. Steel reinforcing and epoxy are a more conventional solution. However, fiberglass rods and cementitious grout is probably a better solution. Fiberglass will never corrode and the cementitious grout is more compatible with a masonry material Cementitious grout is less expensive and less likely to find its way through small holes in the adobe walls. Not only is the ultimate structural performance greatly improved but damage to the adobe walls is also severely limited by the doweling effects of the vertical center cores.

The type of retrofit system implemented on a building might depend on the goals of the retrofit solution:

1. Minimal impact on historic fabric and protection of life-safety will provide one solution. In this case, much of the building may suffer severe damage and local sections may even partially collapse during a large to moderate earthquake.

2. An intermediate approach can often be obtained by adding additional straps or cabling. Because the walls of the Rancho San Andres Castro Adobe are so thick, there are limited possibilities for these types of intermediate measures.

3. The more intrusive approach with maximum structural integrity would involve the placement of vertical center core rods at approximately four to six feet on center in combination with the minimal system already installed. In the case of the Rancho San Andres Castro Adobe, the use of center core rods on the gable end walls could be used to eliminate the necessity of attaching the gable end walls at the second floor level.

IV. Fundamental Structural Approaches

The basic approaches used to address the seismic retrofit of adobe buildings presented herein are based upon the premise that adobe buildings and adobe materials have many beneficial characteristics. These characteristics should be taken advantage of when designing a retrofit system.

Wall thickness is essential for the reasonable seismic performance of adobe buildings. Thin adobe walls have height-to-thickness ratios over 9 or 10. This ratio if referred to as the "slenderness ratio." Moderate thick walls have slenderness ratios of 7 or 8. Thick adobe walls have slenderness ratios of six or less. The second floor walls, the walls of the one-story wing, and the interior walls which are 24 inches thick have slenderness ratios of less than 5. The first floor walls of the two-story building which are 36 inches thick have a slenderness ratio of just over 3. The walls of the Rancho San Andres Castro Adobe are thick and will be very beneficial in terms of it's future seismic performance.

Even though the walls of the building are thick, additional seismic retrofit elements will greatly improve the future seismic performance of the building. The following are three types of retrofit systems to consider:

1. Basic System: The basic system for the retrofit of two-story adobe buildings is fundamentally comprised of attaching the adobe walls to the roof and floor system. The roof is typically anchored to the adobe walls by a system that connects the roof framing to the adobe walls. The anchors to the adobe walls are embedded approximately 24 to 30 inches using an epoxy or cementitious grout and spaced at a distance equal to 1-1/2 to 2 times the thickness of the walls. Refer to Figure 1.

   The floor system is anchored to the walls by attaching the floor framing to a perimeter horizontal steel cable. The corner detail for the cables is provided in Figure 2.

   In order of importance, the anchorage at the roof level is significantly more important the the anchorage at the floor level. Because there is no current work proposed at the floor levels, the anchorage at the floor levels is not being addressed as part of the current work.

2. Intermediate System

   A second element that has large beneficial effects on the in-plane and out-of-plane performance of adobe walls is an upper horizontal cable that runs on both sides of the upper portion of a wall just above the door and window openings. The horizontal cables are connected via cross-ties that are tied through the adobe walls.

   Upper walls cables may be required if the roof system has little in-plane stiffness, as is the case with many roofs with spaced sheathing. Partial plywood diaphragms can be used. Full plywood diaphragms are generally unnecessary and may have negative impacts on shear walls that are overloaded by the stiffening effects of the full plywood diaphragm.

   The use of secondary vertical straps is of limited use at the Rancho San Andres Castro Adobe, because the walls are thick and apparently in good condition.

3. Maximum security system

Small diameter center core rods are the primary elements to be added to the structural retrofit system. As stated earlier, these elements would significantly improve overall structural performance and reduce the extent of damage during moderate, large and major earthquakes. Diagrams of these basic structural systems are provided on Sheet SR0.1.

V. Structural Retrofit Recommendations for the Rancho San Andres Castro Adobe

The most elegant solution for the San Andres Castro Adobe is the simplest. The solution includes full-height center core rods in all of the perimeter walls, anchorage of the walls at the tops to the roof diaphragm and strengthening of the roof system with a plywood diaphragm. The center core elements are illustrated on Sheet SR1.1 and the roof diaphragm is illustrated on Sheet SR1.2.

This solution is proposed for the following reasons:

1. The building has suffered considerable earthquake damage and the center cores will help keep all the damaged sections of wall in place.
2. The second floor framing has been historically anchored to the walls and this system has worked for tieing the second floor framing to the walls. Unfortunately, it is difficult to figure the strength of the second floor system into the retrofit system without adding plywood on top of the existing floor.
3. The walls are thick enough the satisfy the slenderness ratio requirements of the Uniform Code for Building Conservation (UCBC) which is adopted directly by the California State Historic Building Code (SHBC) even when using the full height of the adobe walls.

Although another less-secure system without center cores (as discussed in the previous section) might be possible, given the three items listed above, another system is not recommended.

VI. Recommendation for Second Floor Framing

The floor framing system that supports the second floor of the San Andres Castro Adobe is very light-weight even by historical standards. The span of 22 feet across the building is larger than typical in residential buildings of this type and era and the depth of the beams of only 5.5 inches is also shallower than typically observed. Therefore, the strength of the floor system is well below current standards.

The goal in the preservation of this building is to open up the second floor rooms such that the area directly above Room 103 (mostly Room 203) is entirely open. To accomplish this goal, it requires the removal of the vertical rods anchored to the roof system that now support the second floor framing.

Several options have been considered for strengthening the existing floor. The requirements considered are first to provide sufficient strength based upon current code standards of 40 pounds per square foot (psf) live load.

Deflections usually are the governing criteria for the design of wood-framed floors in modern construction. Strength is usually a secondary concern for floor joists. Even when using the minimum criteria for the maximum live load deflection of L/360 (L = length), floor are usually perceived as "too bouncy." Nevertheless, the primary concern is to provide sufficient strength for the floor system. Then, this report presents optional measures that may be undertaken to address concerns if the floor is too bouncy.

The deflections of the floor system are considerably greater than those provided by current code standards. In fact, with the basic proposed system, the deflections would be about three times greater than the current code standards. Additional measures may be undertaken to attempt to reduce excessive deflections and will be discussed at the end of this section.

Several options were investigated for stiffening the floor system and are illustrated on Sheet S5.1. The measures are as follows:

1. Option 1: Add 1/4-inch steel plates on either side of the existing beams and screw them securely to the beams. The plates would be the same depth as the existing floor joists.

2. Option 2: Insert new steel beams in between the existing floor joists. These steel beams could be slightly shallower than the existing floor joists. The beams would need to be supported by the existing adobe walls on either end.

3. Options 3 and 3A are similar. The use of the large girder down the center of the room would allow sufficient strength and stiffness to be comparable to Options 1 and 2. In option 3A, the girder is raised to match the top height of the existing joists. Option 3A would require cutting each joist at mid-span to make roof for inserting the girder. New posts and footing would be required at each end of the girder.

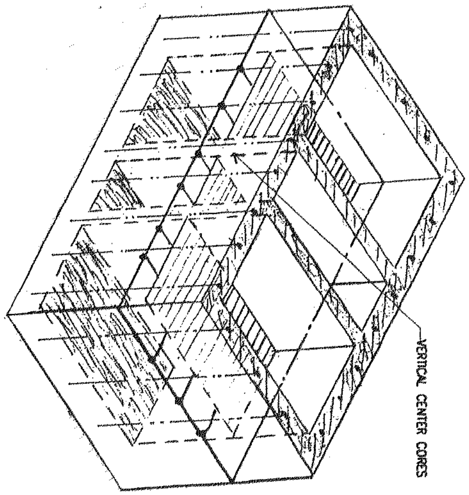
4. The final options is similar to Options 3 and 3A but would use a light-weight steel truss as the girder at the center of the roof. The legs of the truss would be approximately 2-inch angles but would allow some visibility through the truss as compared the that provided by the solid beams in Options 3 and 3A.

All of the above flooring systems will be quite flexible but do have adequate strength do support the standard live loads as designed for by current building codes.

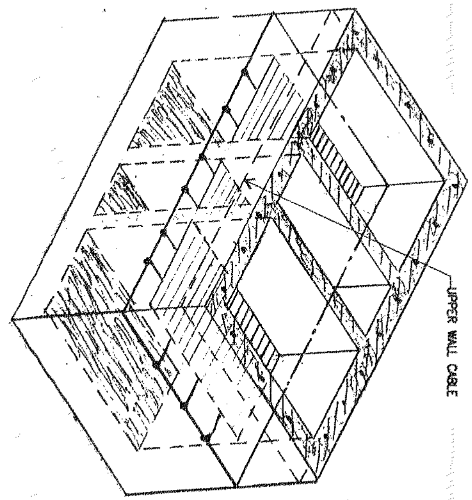
Two measures could be adopted after the strengthening is undertaken if the flexibility of the flooring system is unacceptable.

A. The floor could be overlain with a new floor deck. This may add some stiffness to the floor system by increasing the depth of the entire floor assembly. The floor assembly includes the floor joists and girders (if used) as well as the floor decking. The bigger contribution to the perceived flexibility of the floor system is simply the addition of mass to the entire system. The period of vibration of the floor system is increased with a greater mass.

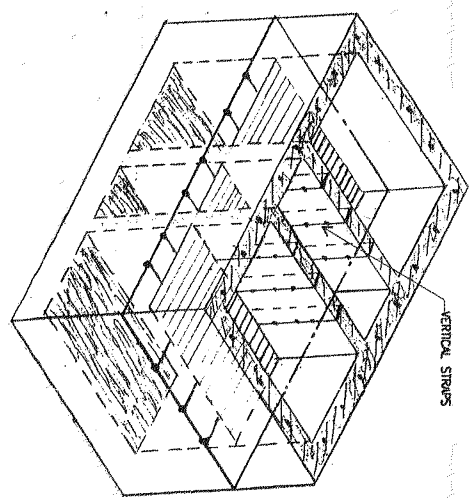
B. Under the new floor deck, steel straps could be placed on top of each floor joist and then heavily screwed into the joist through the existing floor decking. This would created a composite member of the new steel plate, the existing floor deck and the existing floor joist. The new floor deck (Item A) would then need to be raised or cut out around the new steel straps.



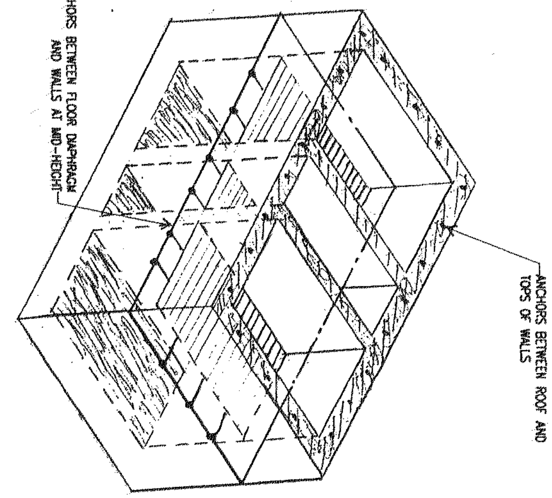
HIGHER PROTECTION AGAINST DAMAGE OR COLLAPSE
CENTER CORES RODS



ADDITIONAL SAFETY MEASURES
UPPER WALL CABLE



ADDITIONAL SAFETY MEASURES
VERTICAL STRAPS ON INTERIOR WALLS



MINIMAL RETROFIT
ANCHORS AND ROOF AND FLOOR LEVELS

SHEET **SR0.1** 1 OF 5 SHEETS

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GENERAL
SEISMIC RETROFIT
STRATEGIES

CASTRO ADOBE
Rancho San Andres
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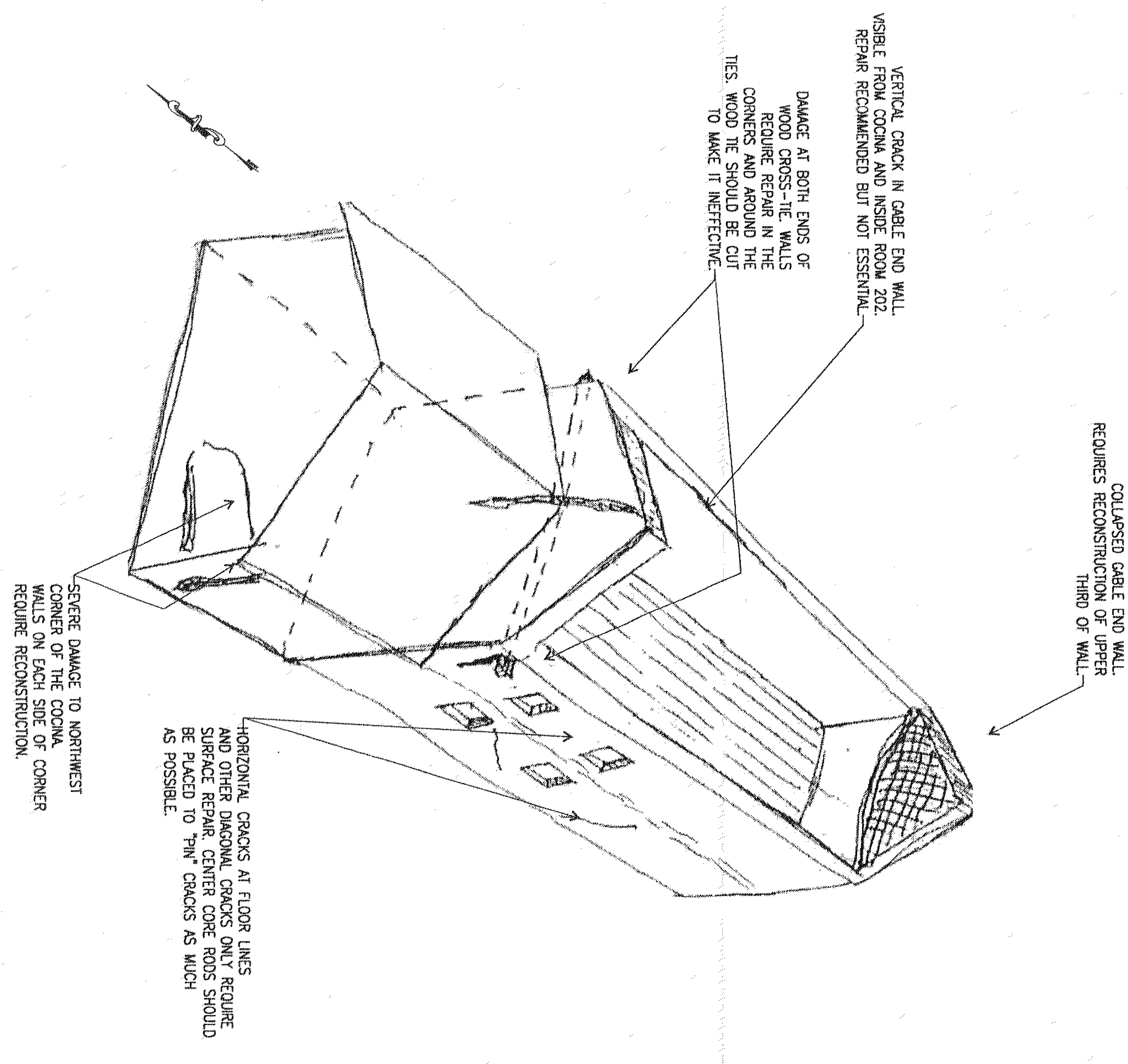

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SHEET **D1.1** 2 OF 5 SHEETS

STRUCTURAL DAMAGE REPAIR SUGGESTIONS

CASTRO ADOBE

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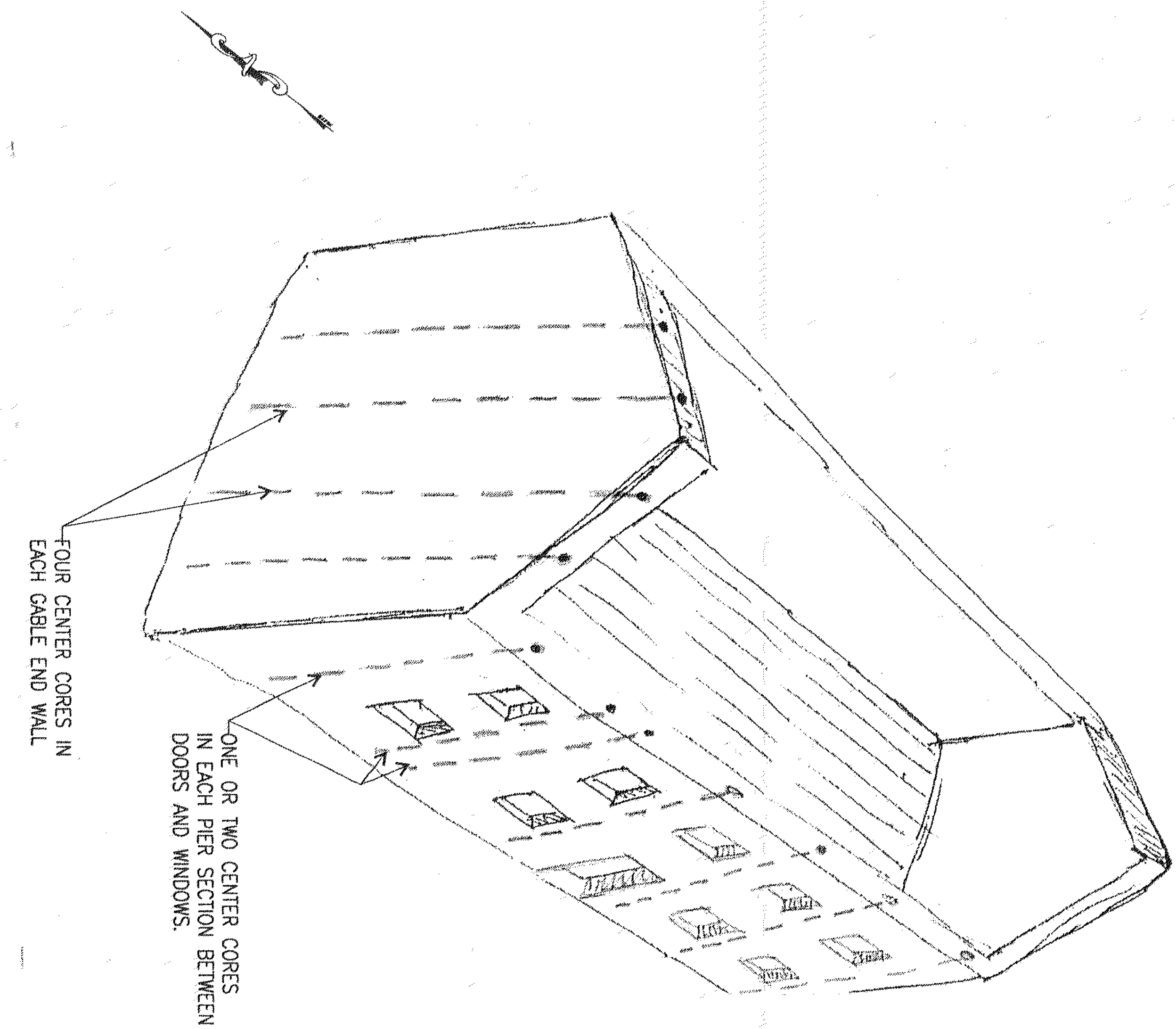

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SHEET
SR1.1
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STRUCTURAL RETROFIT
CENTER CORE ELEMENTS

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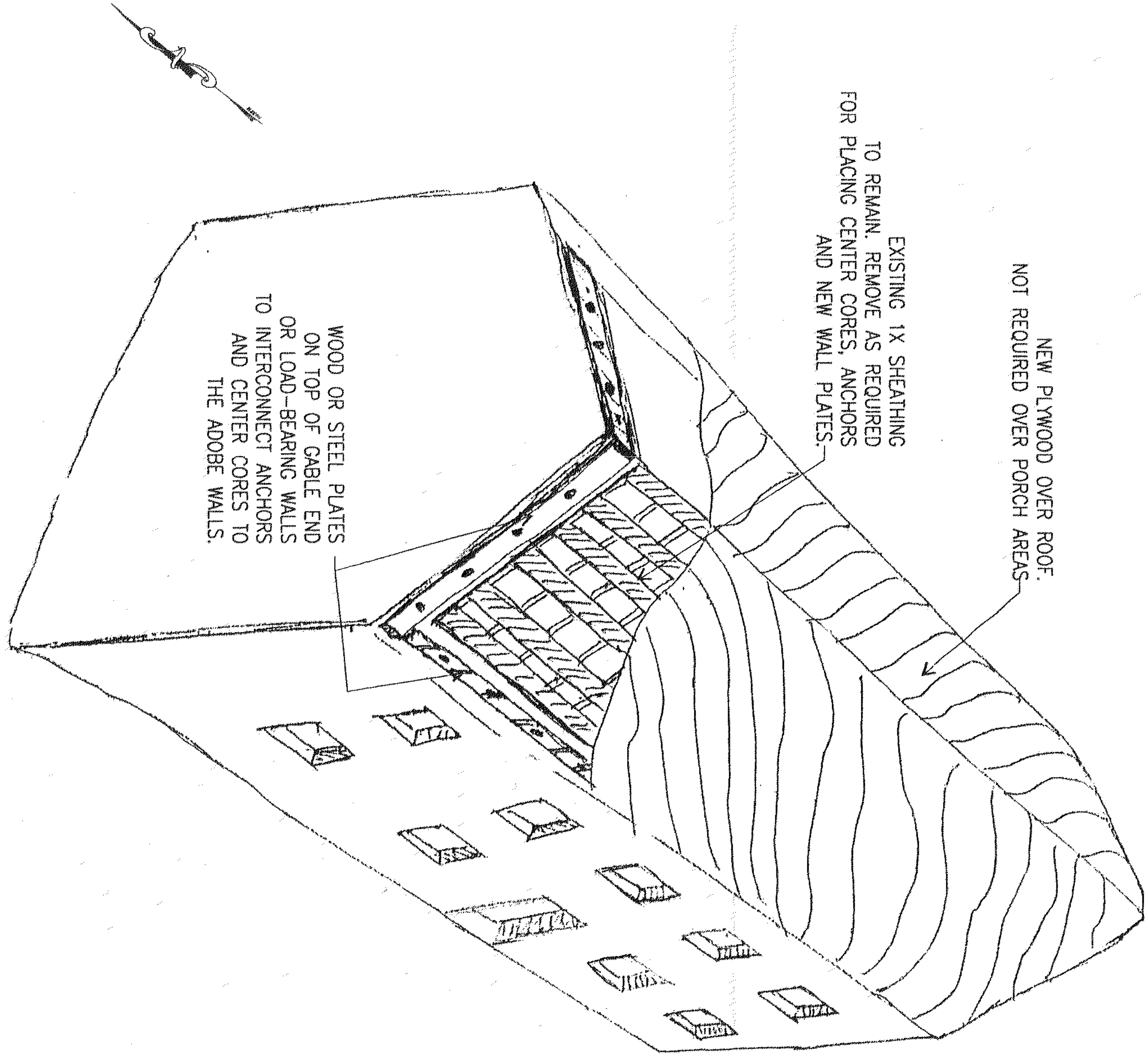

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SHEET
SR1.2
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STRUCTURAL RETROFIT
MISC.
STRUCTURAL ELEMENTS

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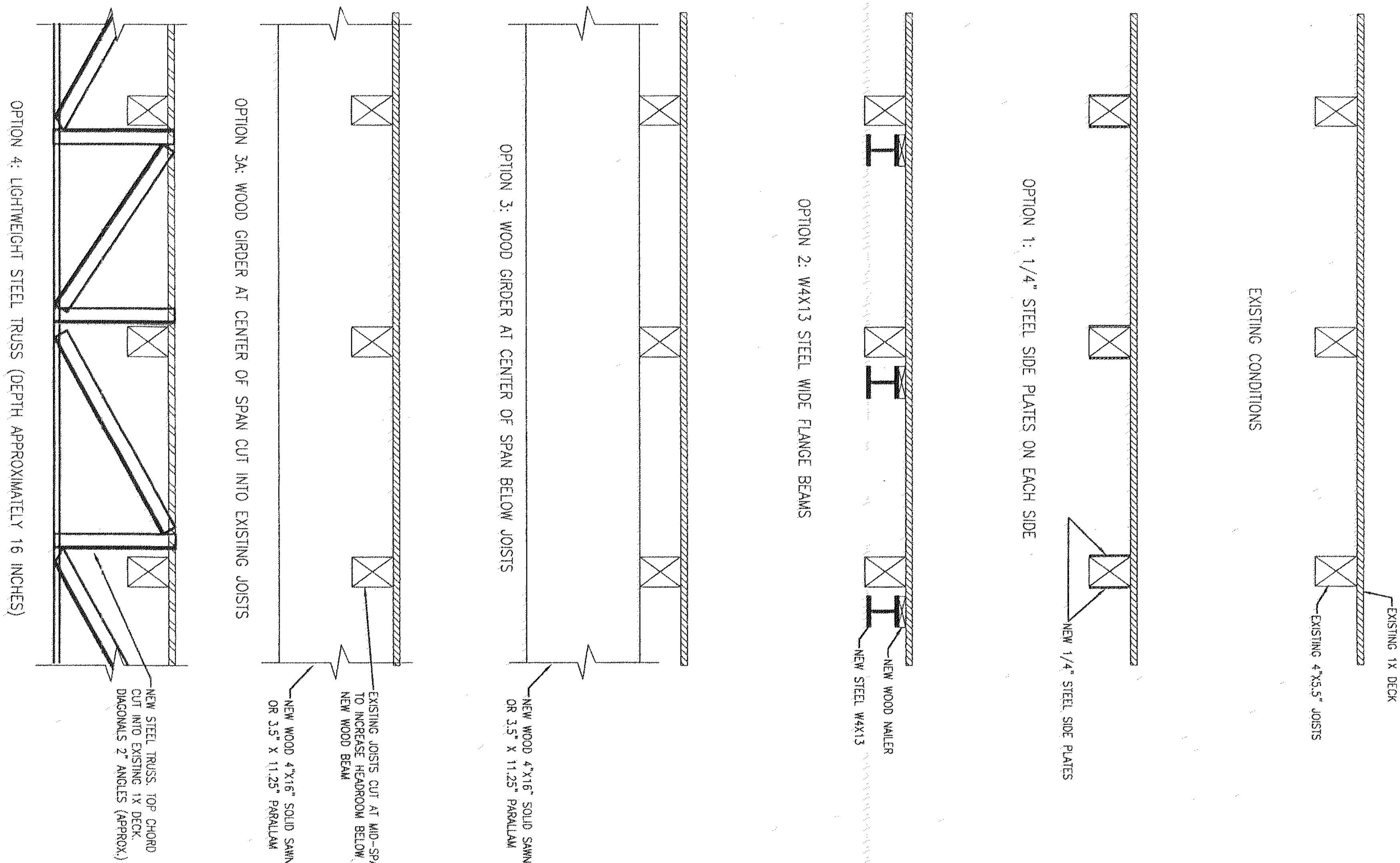

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SHEET
S5.1
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STRUCTURAL DETAILS
FLOOR FRAMING OPTIONS

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